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Improving of the cod biomass estimation by SAM for use in the assessment of Northern Shrimp (*Pandalus borealis*) in West Greenland.

by

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Introduction

The West Greenland stock of *P. borealis* is assessed annually using a quantitative surplus-production model. The stock dynamics of the model include a term for predation by cod, which is considered to vary with changes in the biomass of the offshore cod stock and its distributional overlap with the stock of shrimps. In 2019 the cod stock estimation was performed by a state-space assessment model (SAM) (Nielsen & Berg, 2014) and worked as input to the shrimp assessment model. Previously the cod stock was estimated based indices derived from an early virtual population analyze and research trawl surveys (Kingsley, 2014).

The SAM model includes catch at age data from the commercial fishery beside survey catch at age data and produced a much more smoothed development of the cod biomass. Whereas the cod biomass was fluctuating and dependent on the occurrence of one or two hauls with very large catches when only based on survey data (Rigét & Burmeister, 2019). At the last NIPAG meeting it was agreed to apply the SAM estimation of the cod stock biomass.

However, the retrospective plots from the SAM model showed that the cod stock biomass systematic was over-estimated and estimates were reduced when data for a new year became available. Mohn's rho was = 0.7. Furthermore, were the confidence limits of the estimated cod stock biomass very broad (Rigét & Burmeister, 2019).

Two research survey (Greenland and German) act as tuning fleets in the SAM assessment. Since 2015 no new data from the German survey has been available and the coverage has in several years during the last ca. 20 years been restricted to NAFO Div. 1D, 1E and 1F. The Greenland survey has a coverage from NAFO Div. 1A in the north to Div. 1F in the south but only covers the period from 1992 until today. Here we present the results only include the Greenland research survey as tuning fleet in the SAM assessment.

Materials and methods

Survey data

The Greenland research survey covers the period from 1992 to 2020 and the area from NAFO Div. 1A in the north to Div. 1F in the south. The survey is a stratified random survey targeting both fish and shrimp. Since 2000 the stations have been allocated to strata with the objective to minimize the variances of the shrimp,

Atlantic cod, and Greenland halibut biomass (see Kingsley *et al*., 1999). The German research survey covers the period from 1982 to 2015 and NAFO Div. 1C, 1D, 1E and 1F. However, no hauls have been carried out in Div. 1C in some years since 2000 (Table 2). The survey is a stratified random survey covering depths down to 400 m.

SAM model

The SAM assessment was performed with both research surveys as tuning fleets and with only the Greenland research survey. The model configuration was like the configuration used in last year assessment including an emigration to East Greenland/Iceland and a similar correlation and variance structure between ages for the fishery, survey, and process parameters (Rigét & Burmeister, 2019).

Results and Discussion

Survey comparisons

The area coverage of the Greenland and the German survey have differed (Table 1 and 2). The Greenland survey cover NAFO Div. 1A in the north to Div. 1F in the south and depth down to 600 m. While the German survey cover NAFO Div. 1D to 1F and in several years only 1C to 1F down to 400 m. The cod distribution in the West Greenland area has in recent decades been in the southern part of West Greenland, however in some years cod are also found north of Div. 1C and outside the German survey area (Figure 1).

The external consistency between the Greenland and the German survey show R^2 values between 0.5 and 0.6 for age groups 3,4,5 and 8, while for other age groups R^2 values were low (Figure 2). The biomass index estimated by the two surveys was relatively high correlated ($R^2 = 0.76$) for the period 1992 to 2015 (Figure 3).

SAM results using both surveys and using only the Greenland survey

The Spawning stock biomass (SSB) in recent years is less than half when using only the Greenland survey as tuning fleet compared to using both the Greenland and the German surveys (Figure 4). That the SSB in recent years are lesser than the SSB in the late 1970ies/early 1980ies and not higher as found using both surveys fit the perception of experience Greenland cod biologists. Furthermore, the confidence limits of the SSB in recent years are relatively narrow when using only the Greenland survey, whereas the confidence limits when using both surveys are very width.

The 1984 year-class in West Greenland was very large and mainly of East Greenland/Icelandic origin (Storr-Paulsen *et al.* 2004), giving rise to a total catch in 1989 of around 74,000 tons. The estimated SSB in 1989 using only the Greenland survey is around 47,000 tons, while is it only estimated to around 20,000 tons when using both surveys. About 50% of the 5 years old cod are mature it appears more reasonable with a SSB of 47,000 tons than 20,000 tons in 1989 having the total catch of 74,000 tons in 1989 in mind.

Retrospective plots of the SSB

The 5-years retrospective plot of the SSB when including both the Greenland and the German survey as input to the SAM model (Figure 5, right) show systematic over-estimation of the SSB. The SSB is successively revised downward when a new year of data become available. The Mohn's rho is consequently high = 0.72. Including only the Greenland survey in the model results in the 5-years retrospective trajectories are within the confidence limits of the SSB, the Mohn's rho = -0.01 and with no systematic over- or underestimation of the SSB.

ICES have not yet defined acceptable ranges for retrospective patterns (ICES, 2020) but refer to the rule of thumb proposed by Hurtado-Ferro et al. (2015) that for long-lived species Mohn's rho should not be higher than 0.20 or lower than -0.15. The bias of the estimation of cod stock biomass when using both surveys has implications for the West Greenland shrimp stock assessment especially when projecting of the shrimp stock development. The usual approach in the projection of the shrimp stock is to predict a cod biomass in the coming years as found in the present year.

Conclusions

The cod stock biomass has essential importance for the shrimp stock assessment as it is used in risk analysis for future shrimp catch levels. In last year shrimp stock assessment is was introduced to estimate the cod stock biomass using the state-space assessment model, SAM (Burmeister & Rigét, 2019). The Greenland and German surveys differ both by the area and period covered. Since 2015 no German survey data has been available. We believe that these differences can create problems in the cod stock biomass estimation. The German survey has a large influence on the cod biomass estimate and its precision especially in recent years but also on the biomass of the very large 1984 year-class. The perception of Greenland cod biologists is more in accordance with the trajectory of the cod biomass when only including the Greenland in the assessment model than with both surveys included. The present of the German survey in the cod assessment model appear to create a bias of systematic over-estimating the cod biomass, which have negative implication for the West Greenland shrimp assessment. It is therefore recommended only to apply the Greenland survey data as tuning fleet in the cod biomass estimation.

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Table 1. Number of hauls by NAFO Division in the Greenland research survey.

Year/NAFO	0A	1A	1B	1C	1D	1E	1F	Total
1992		92	44	18	18	11	15	198
1993		69	49	21	15	12	13	179
1994		76	58	23	8	9	9	183
1995		83	61	29	13	14	11	211
1996		71	57	29	12	9	11	189
1997		84	56	32	12	12	19	215
1998		77	80	27	19	14	14	231
1999		84	81	33	16	14	17	245
2000		56	62	37	23	14	29	221
2001		60	75	36	24	15	26	236
2002		50	80	32	18	20	27	227
2003		51	63	30	18	15	22	199
2004		54	55	24	22	20	34	209
2005	6	65	56	26	19	23	23	218
2006	5	86	60	26	20	21	31	249
2007	8	73	58	26	27	31	39	262
2008	6	69	61	28	23	25	47	259
2009	8	74	75	28	22	24	48	279
2010	10	95	76	30	23	25	40	299
2011	0	73	64	24	18	12	25	216
2012	0	73	64	21	18	18	26	220
2013	4	73	52	20	13	21	28	211
2014	0	78	57	19	17	23	32	226
2015	0	70	49	24	22	21	36	222
2016	0	59	38	26	14	19	36	192
2017	3	99	52	25	18	25	35	257
2018	0	78	42	26	23	20	35	224
2019	0	86	36	20	18	14	24	198
2020	0	84	51	29	21	23	43	251

Table 2. Number of hauls by NAFO Division in the German research survey.

Year/NAFO	1C	1D	1E	1F	Total
1982	31	23	15	15	84
1983	37	36	22	22	117
1984	38	34	25	24	121
1985	18	36	22	25	101
1986	36	30	23	23	112
1987	44	25	22	26	117
1988	55	33	23	20	131
1989	40	39	11	28	118
1990	26	31	19	27	103
1991	30	30	18	19	97
1992	12	11	12	12	47
1993	16	15	18	7	56
1994	29	21	16	12	78
1995	0	3	17	15	35
1996	10	13	17	15	55
1997	11	10	11	13	45
1998	14	17	17	15	63
1999	15	22	19	12	68
2000	19	21	19	14	73
2001	0	22	20	17	59
2002	0	9	11	12	32
2003	0	13	14	12	39
2004	16	20	15	14	65
2005	0	16	14	11	41
2006	11	12	14	13	50
2007	10	12	11	14	47
2008	5	14	17	14	50
2009	2	10	12	10	34
2010	10	15	16	16	57
2011	0	10	10	13	33
2012	10	18	16	16	60
2013	12	14	17	15	58
2014	10	18	17	16	61
2015	14	11	10	15	50

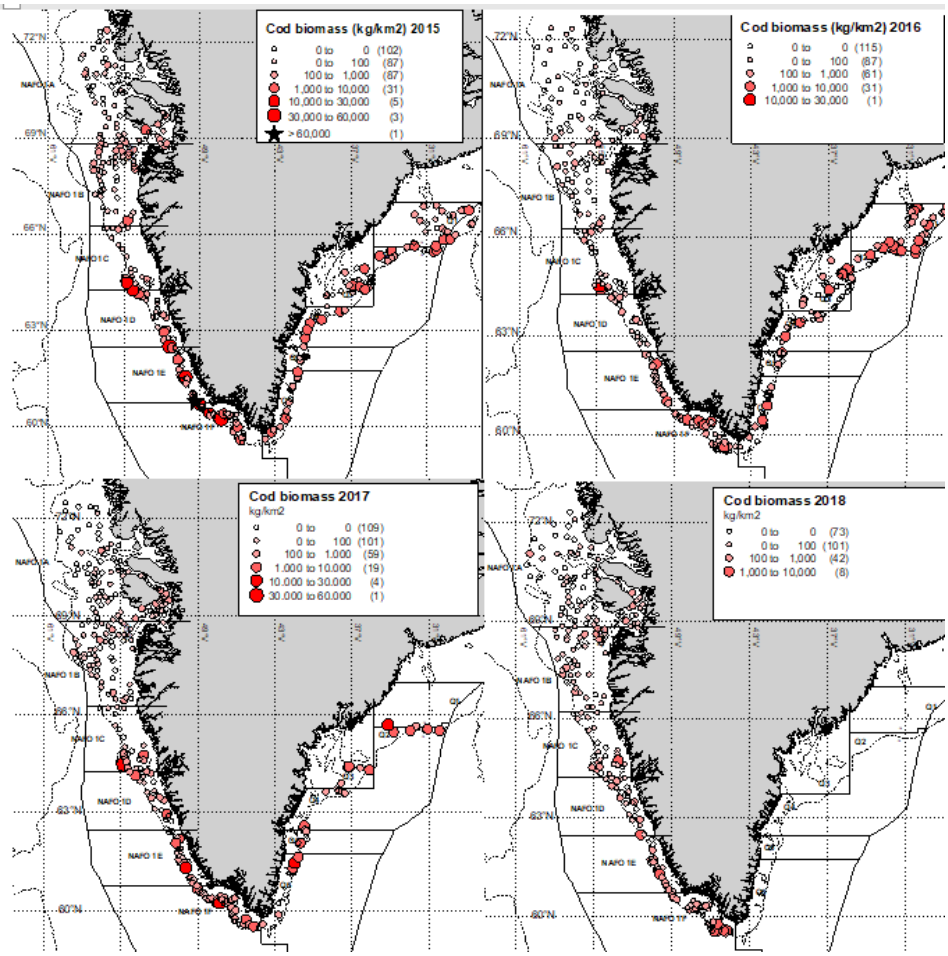

Figure 1. Biomas of cod (kg/km²) by the Greenland Shrimp and Fish survey.

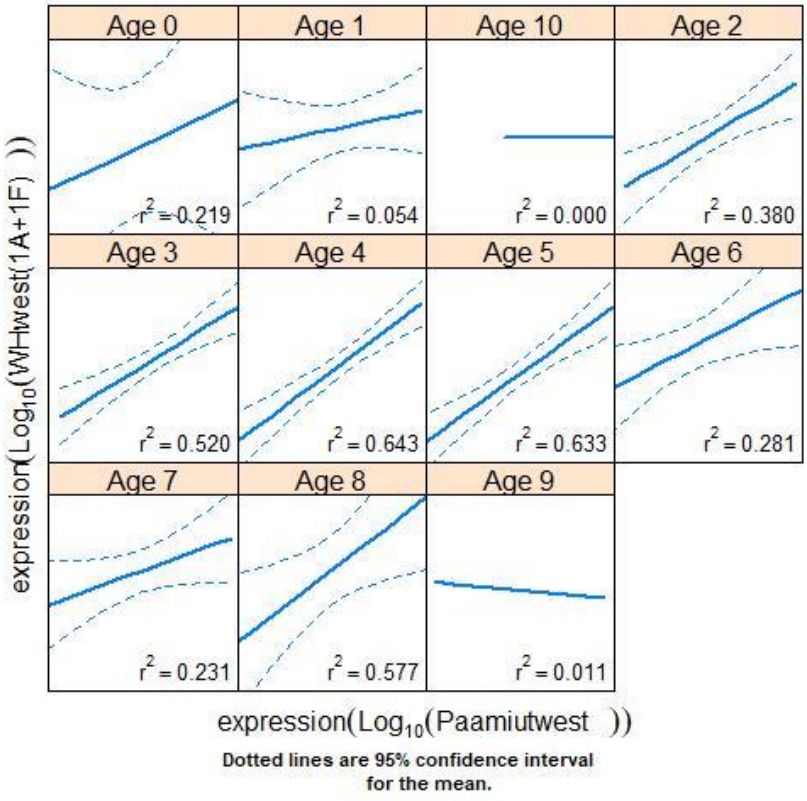

Figure 2. External consistency of the Greenland survey (x-axis) and the German survey (y-axis)

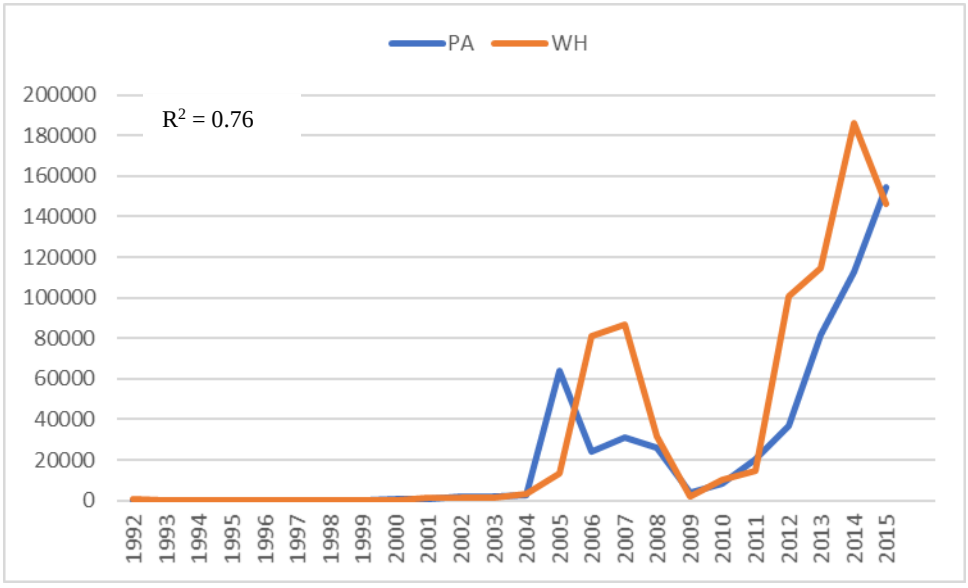

Figure 3. Biomass index (tons) estimates from the Greenland survey and the German survey.

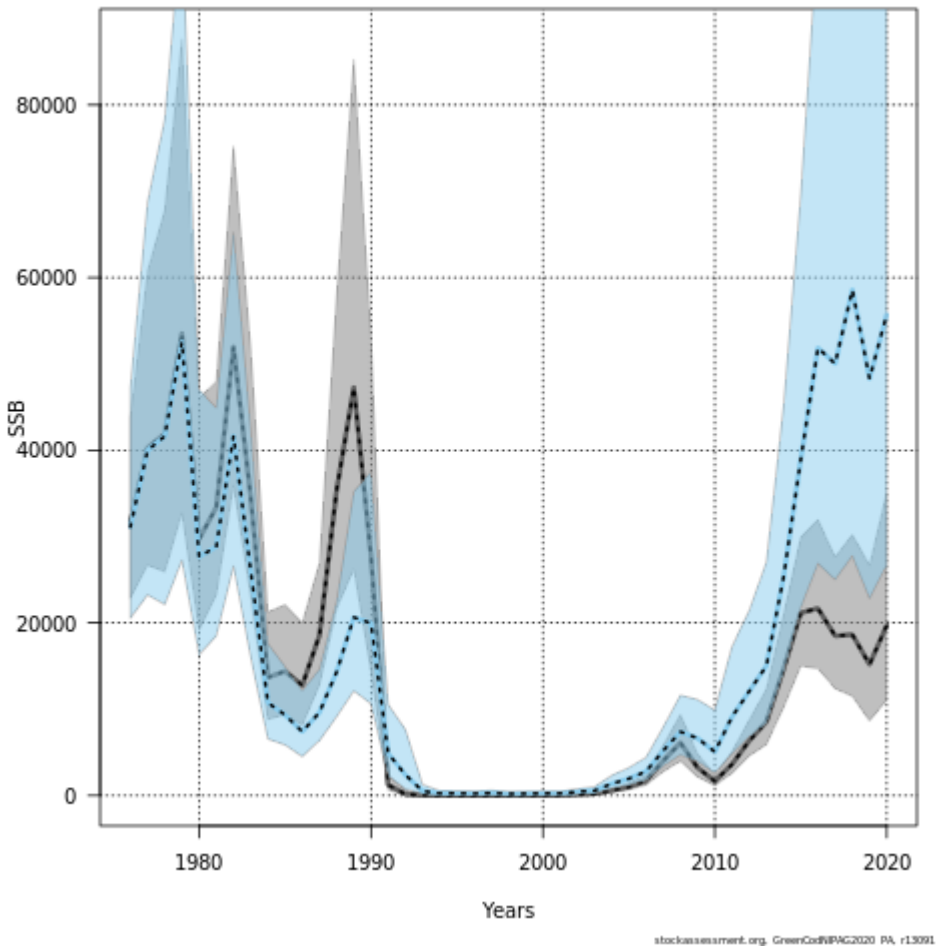

Figure 4. Estimated spawning stock biomass using both surveys as tuning fleets (blue, broken lines) and using only the Greenland survey as tuning fleet (black line).

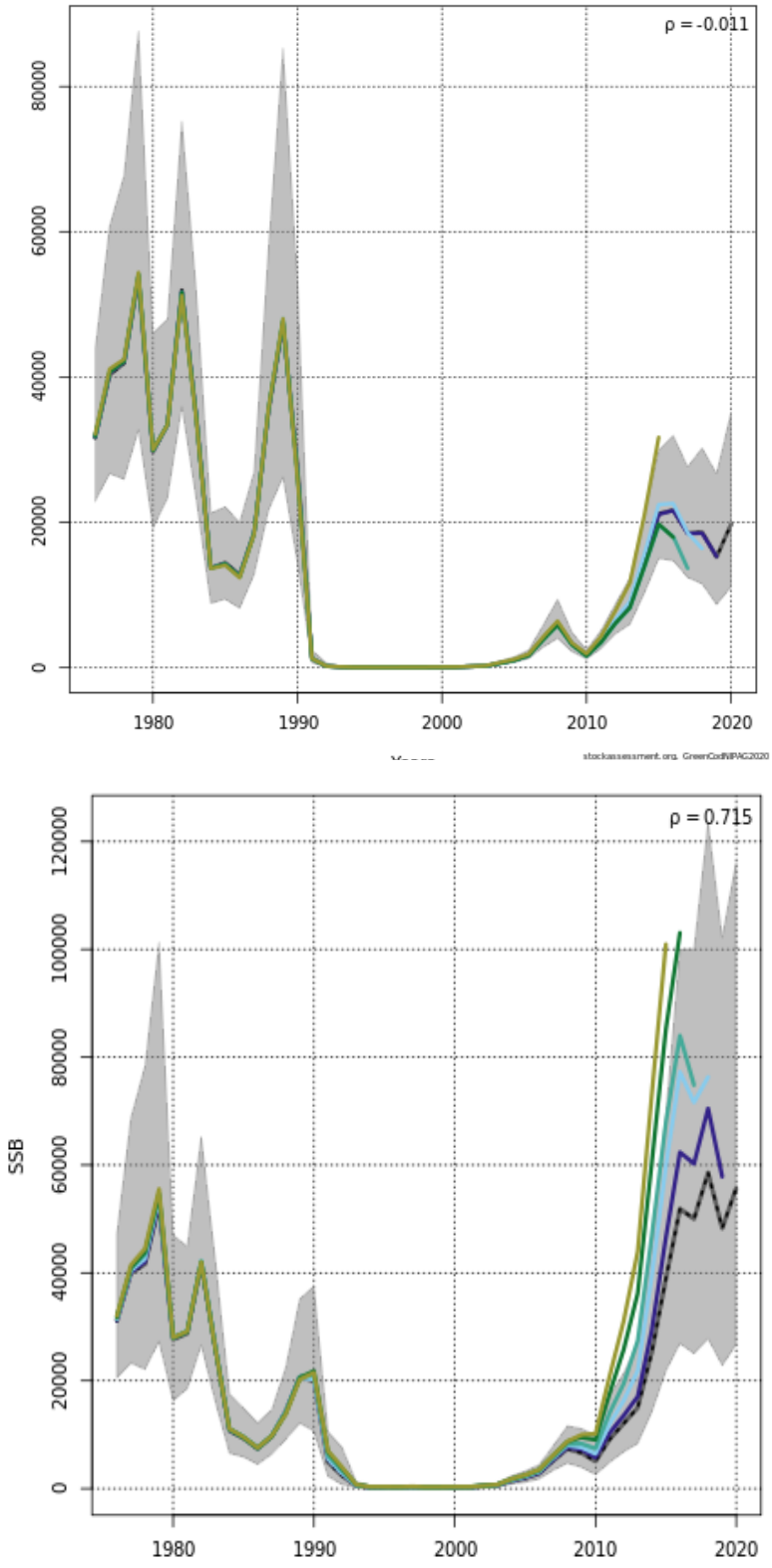

Figure 5. Retrospective plots of SSB. Above: With the Greenland survey. Below: with the Greenland and German survey.